Transformational Propulsion for In-Space Fast Transits

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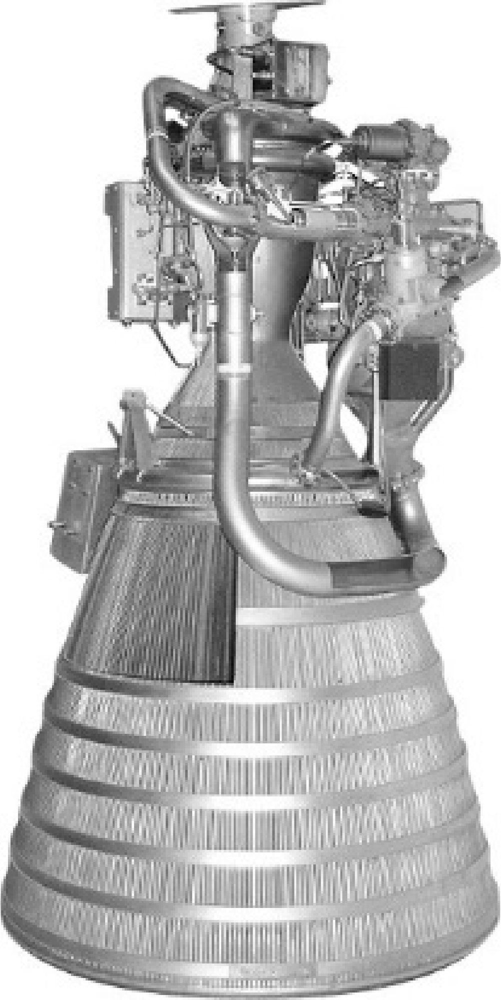
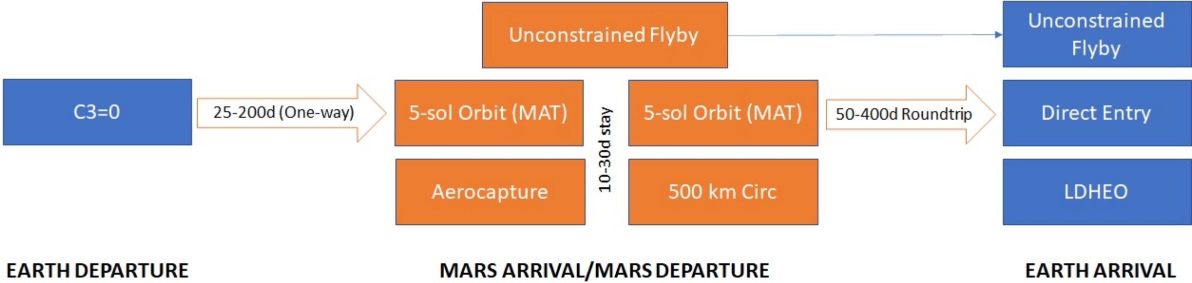




Unconstrained Flyby

C3=0

25-200d (One-way)

5-sol Orbit (MAT)

Aerocapture

10-30d stay

5-sol Orbit (MAT)

500 km Circ

50-400d Roundtrip

Unconstrained Flyby

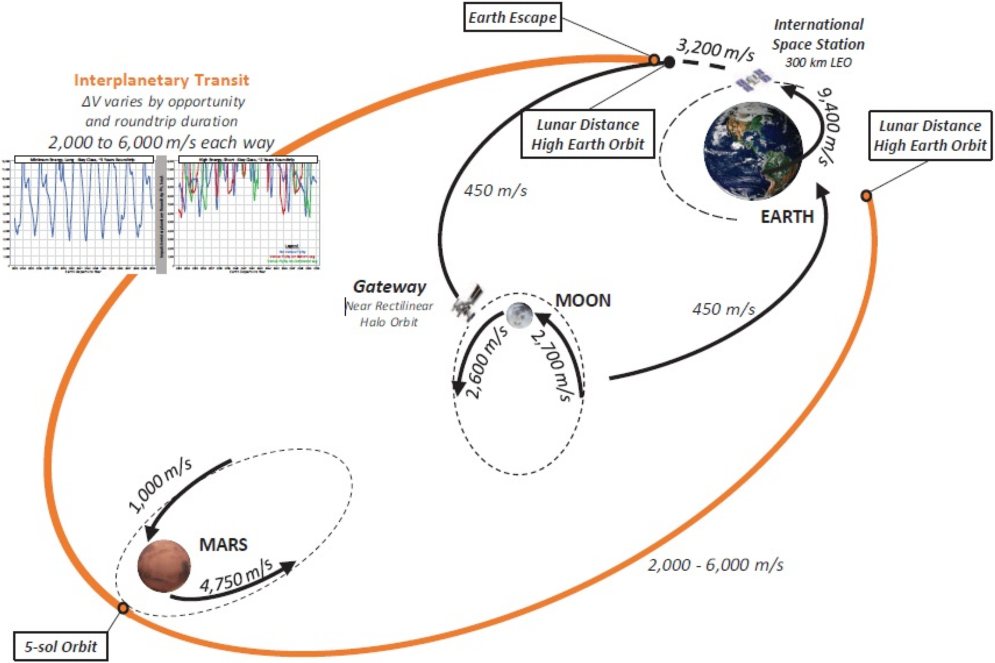
Direct Entry

LDHEO

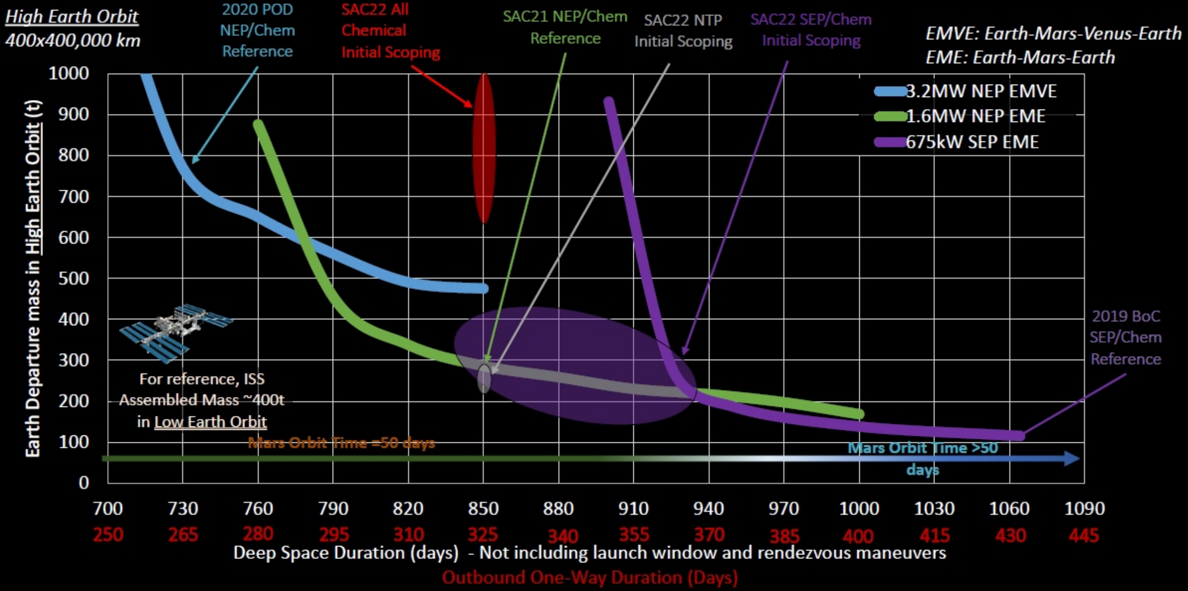
EARTH DEPARTURE

MARS ARRIVAL/MARS DEPARTURE

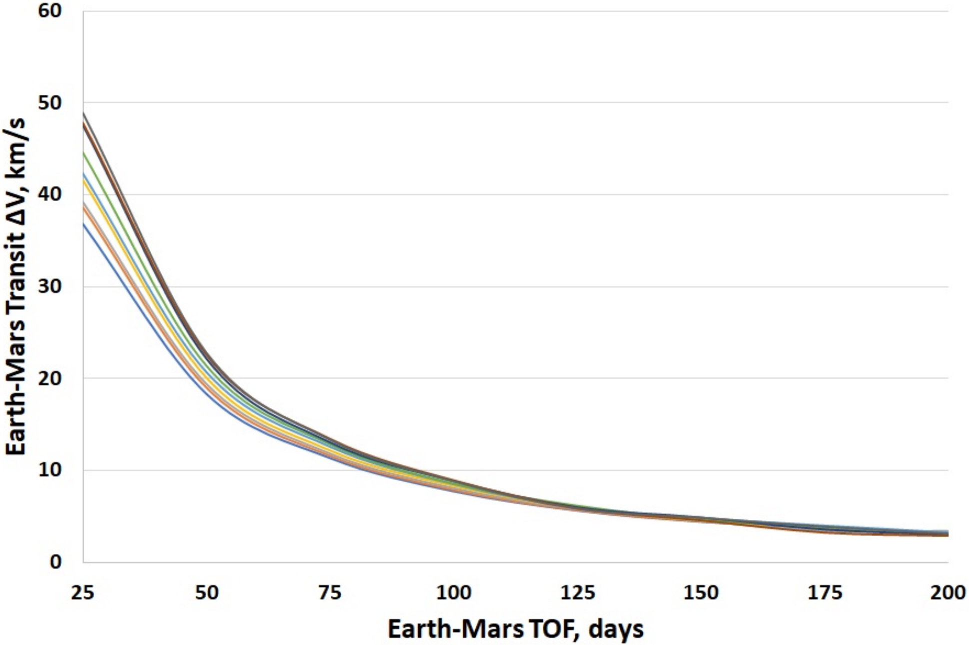
EARTH ARRIVAL

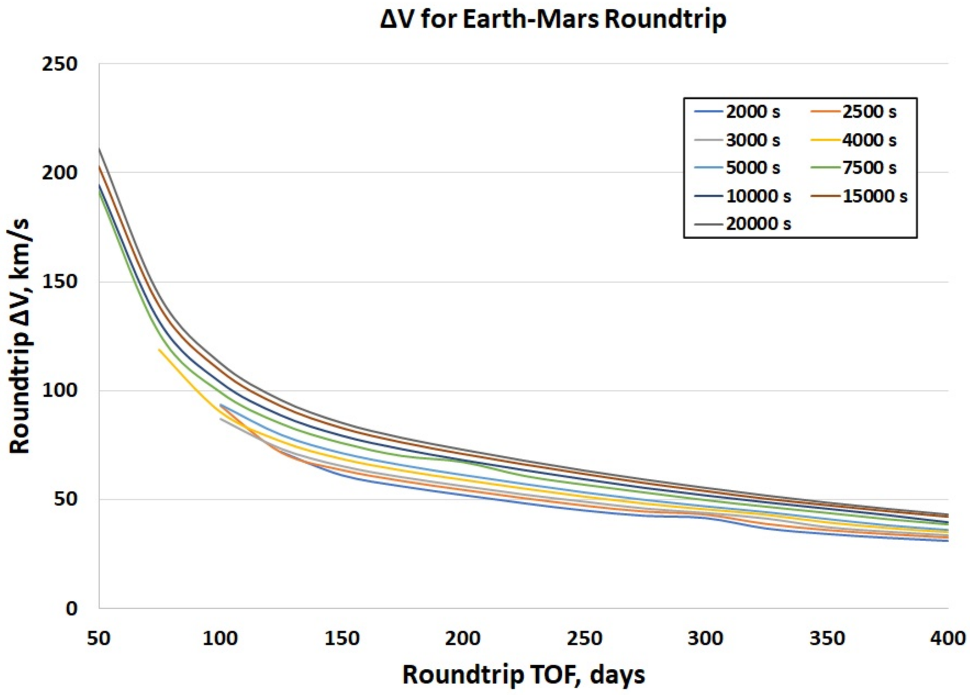

Earth Escape
3,200 m/s
International
Space Station
300 km LEO
Interplanetary Transit
ΔV varies by opportunity
and roundtrip duration
2,000 to 6,000 m/s each way
9,400 m/s
Lunar Distance
High Earth Orbit
Lunar Distance
High Earth Orbit
EARTH
450 m/s
Gateway
Near Rectilinear
Halo Orbit
MOON
450 m/s
2,600 m/s
2,700 m/s
1,000 m/s
MARS
4,750 m/s
2,000 - 6,000 m/s
5-sol Orbit

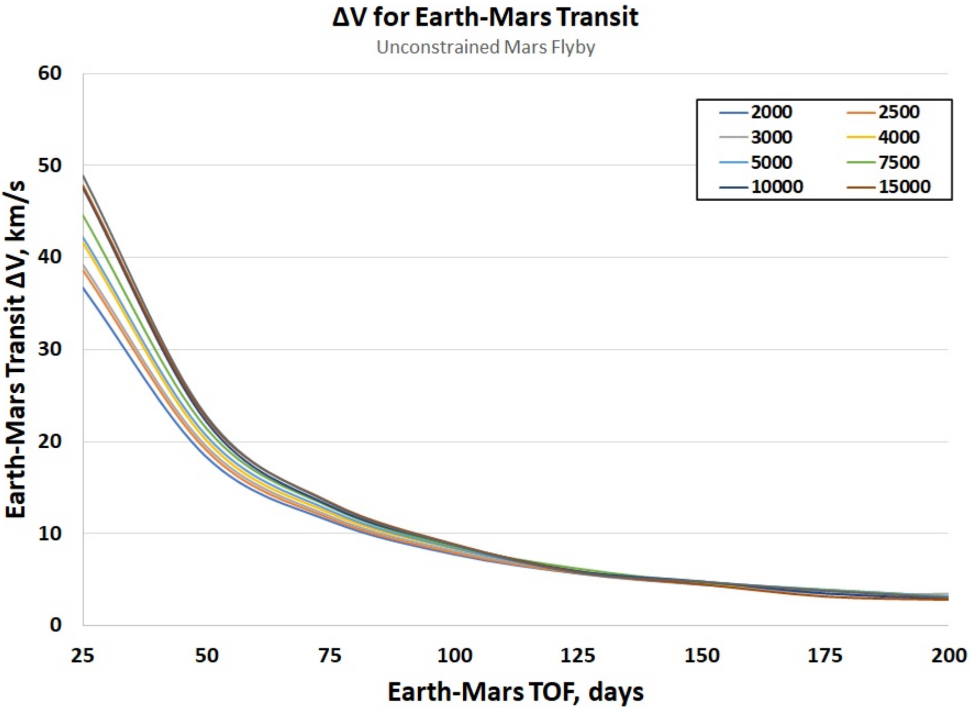
2039 Mission Opportunity Sensitivity to Duration



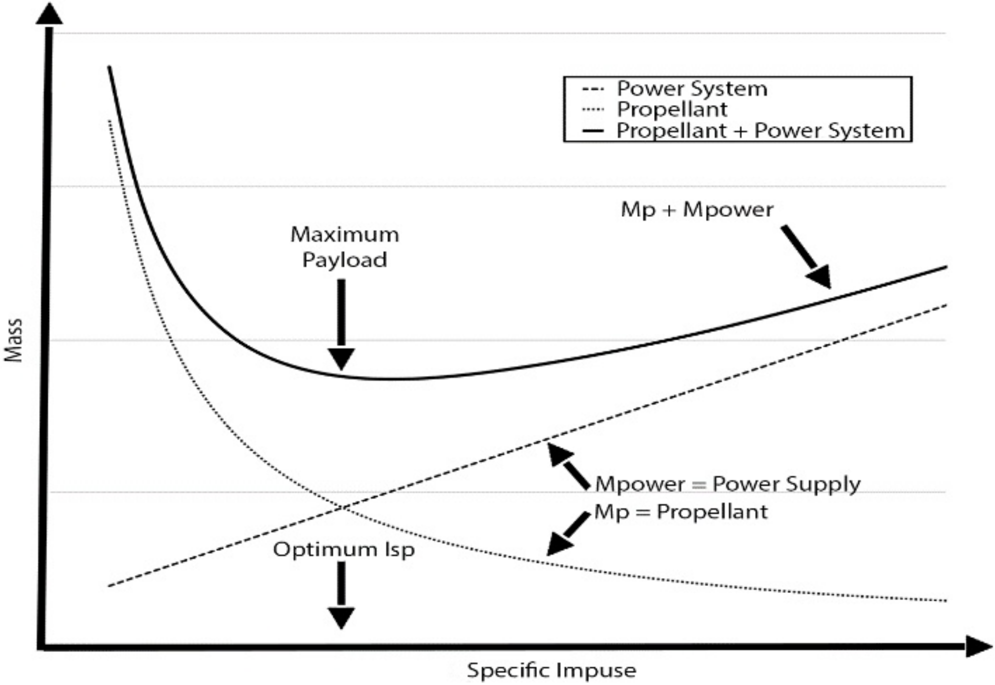
ΔV for Earth-Mars Transit



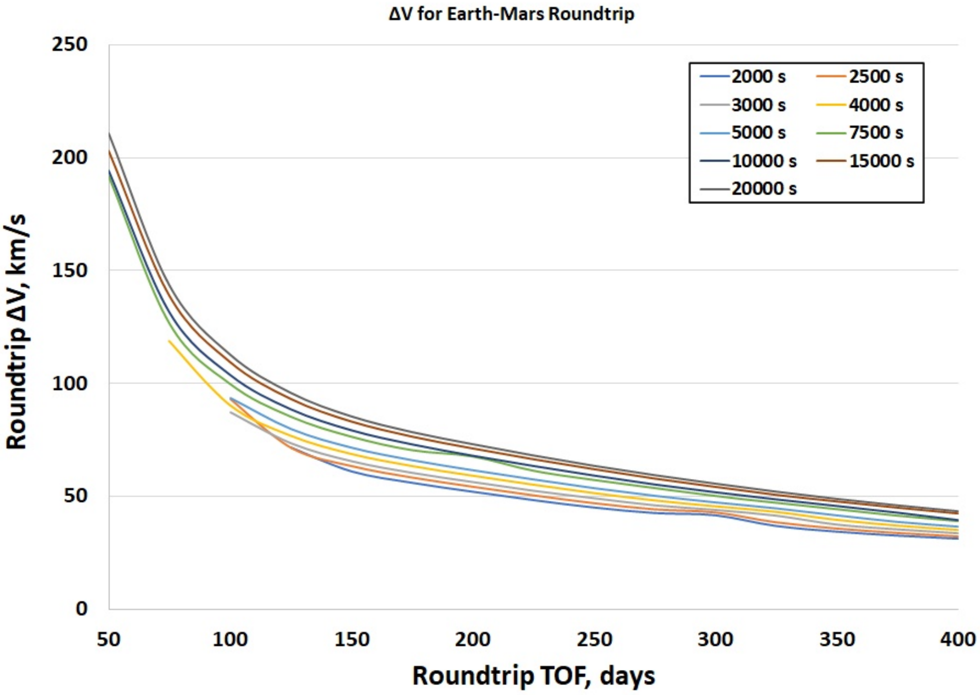

ΔV for Earth-Mars Roundtrip
Roundtrip ΔV, km/s
250
200
150
100
50
0
Roundtrip TOF, days
50
100
150
200
250
300
350
400
2000 s
2500 s
3000 s
4000 s
5000 s
7500 s
10000 s
15000 s
20000 s

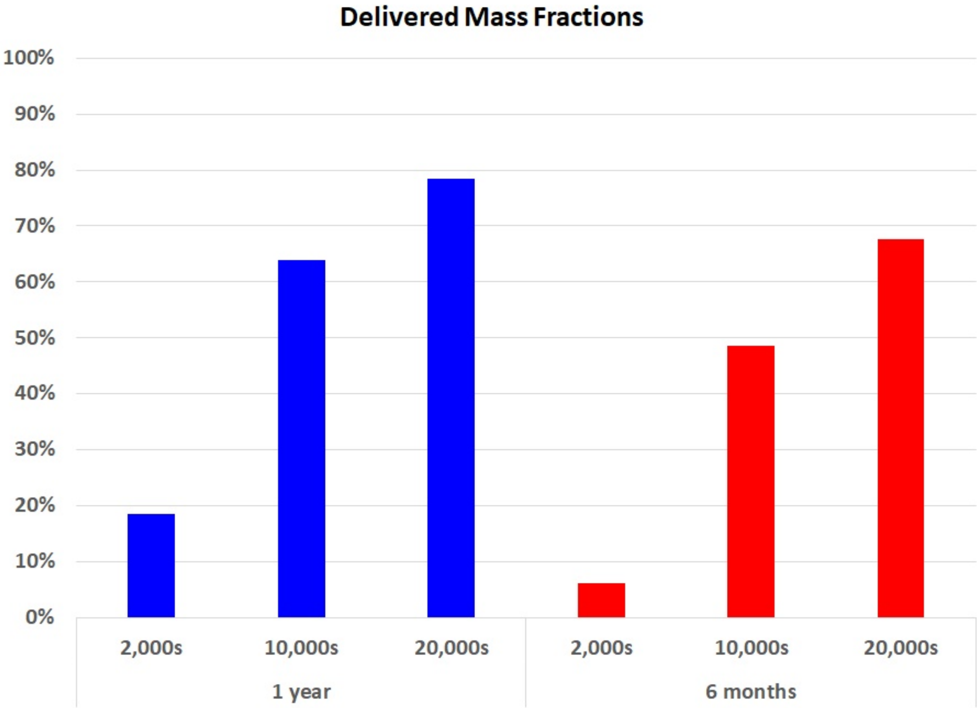

ΔV for Earth-Mars Transit
Unconstrained Mars Flyby
Earth-Mars Transit ΔV, km/s
60
50
40
30
20
10
0
25
50
75
100
125
150
175
200
Earth-Mars TOF, days
2000
2500
3000
4000
5000
7500
10000
15000

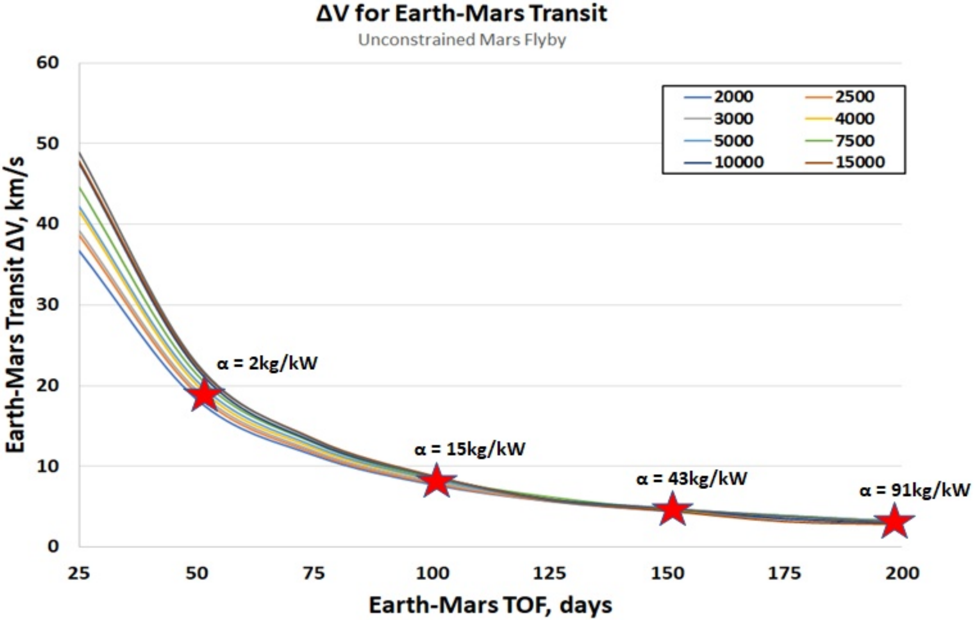
$$P = \frac{g(FI_{SP})}{2\eta}$$



Power System
Propellant
Propellant + Power System
Mp + Mpower
Maximum Payload
Mpower = Power Supply
Mp = Propellant
Optimum Isp
Mass
Specific Impuse

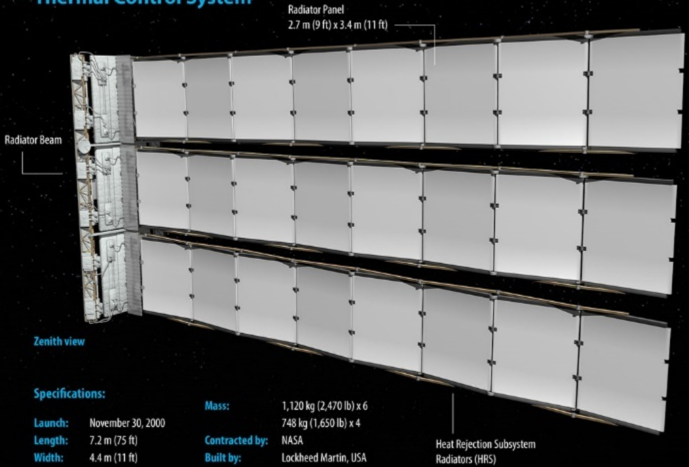

ΔV for Earth-Mars Roundtrip
Roundtrip ΔV, km/s
Roundtrip TOF, days
0
50
100
150
200
250
50
100
150
200
250
300
350
400
2000 s
2500 s
3000 s
4000 s
5000 s
7500 s
10000 s
15000 s
20000 s


Delivered Mass Fractions
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2,000s
10,000s
20,000s
2,000s
10,000s
20,000s
1 year
6 months


ΔV for Earth-Mars Transit
Unconstrained Mars Flyby
Earth-Mars Transit ΔV, km/s
Earth-Mars TOF, days
0
10
20
30
40
50
60
25
50
75
100
125
150
175
200
2000
2500
3000
4000
5000
7500
10000
15000
α = 2kg/kW
α = 15kg/kW
α = 43kg/kW
α = 91kg/kW

Subsystem	SOA	Near Term	Mid-Term
CTE-1: Power Generation	16.5	6	4.5
CTE-2: Power Conversion	10	3	2
CTE-3: PMAD	6	4	2
CTE-4: Propulsion	5.5	5	2
CTE-5: Heat Rejection (w/o deployment mechanisms)	22 (13)	(6)	(2.5)
Total System, kg/kWe	51	24	13

Thermal Control System


Radiator Panel
2.7 m (9 ft) x 3.4 m (11 ft)
Radiator Beam
Heat Rejection Subsystem Radiators (HRS)

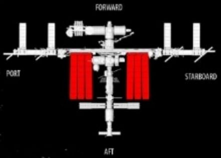
Zenith view

Specifications:

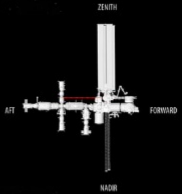
Launch: November 30, 2000
Length: 7.2 m (75 ft)
Width: 4.4 m (11 ft)
Mass: 1,120 kg (2,470 lb) x 6
748 kg (1,650 lb) x 4
Contracted by: NASA
Built by: Lockheed Martin, USA

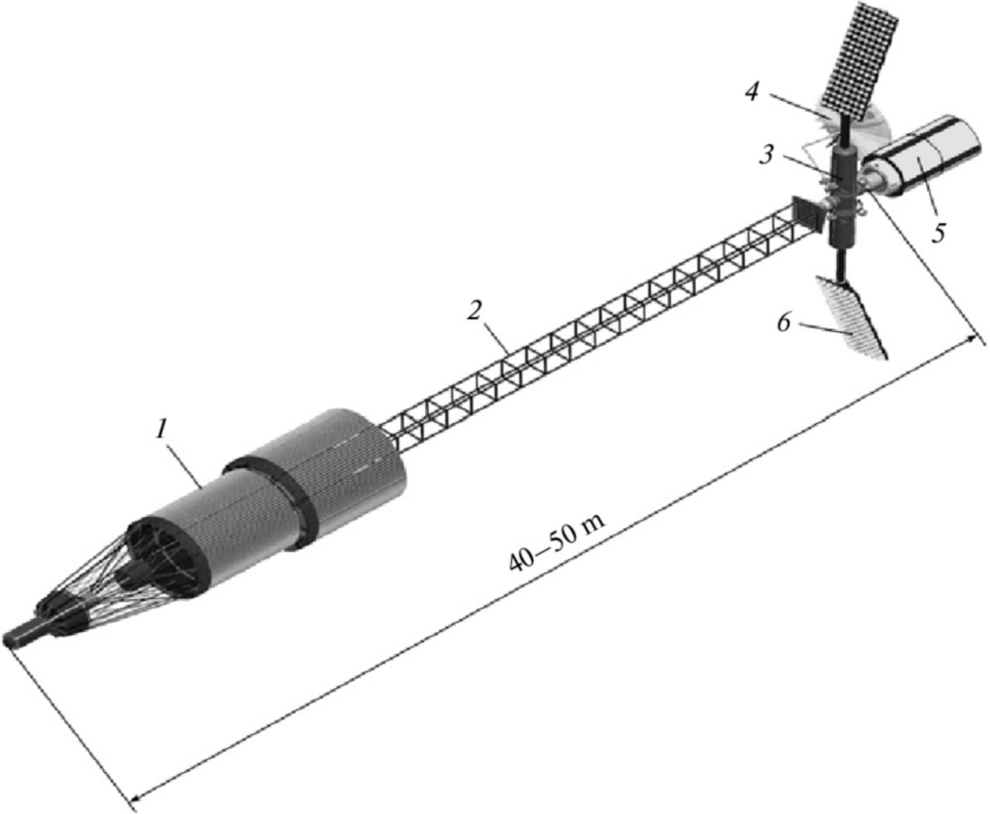
Location on the ISS configuration

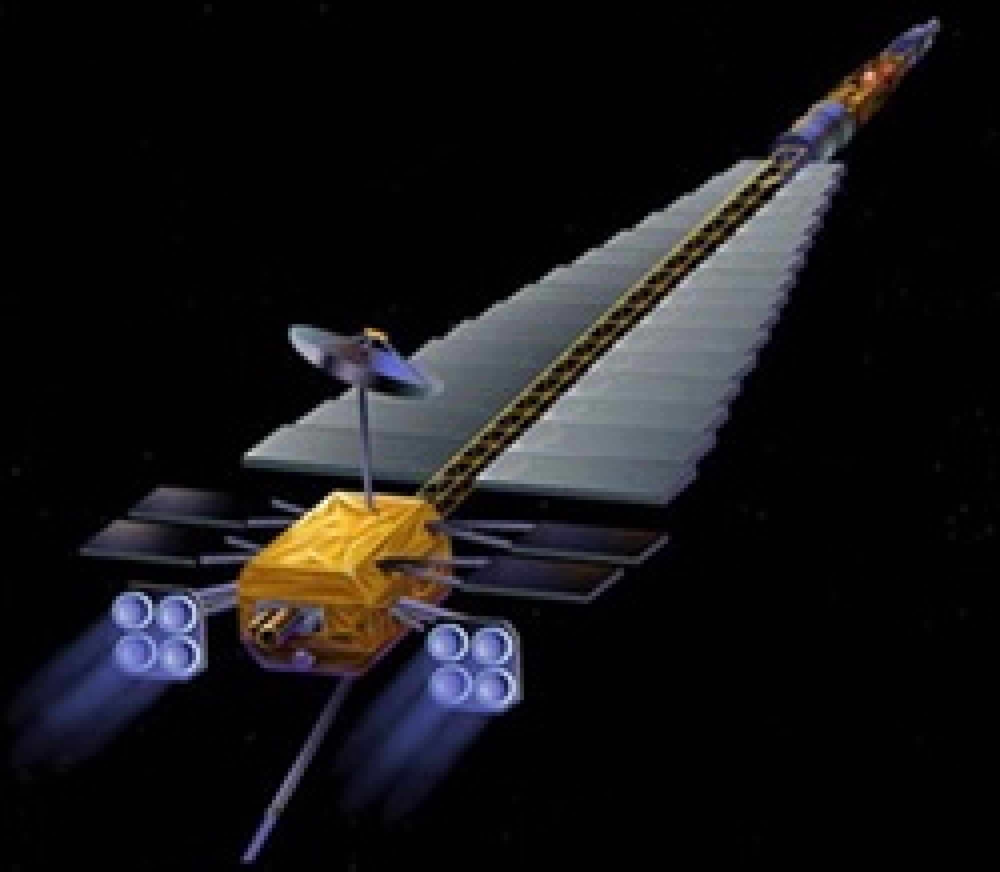
Zenith view

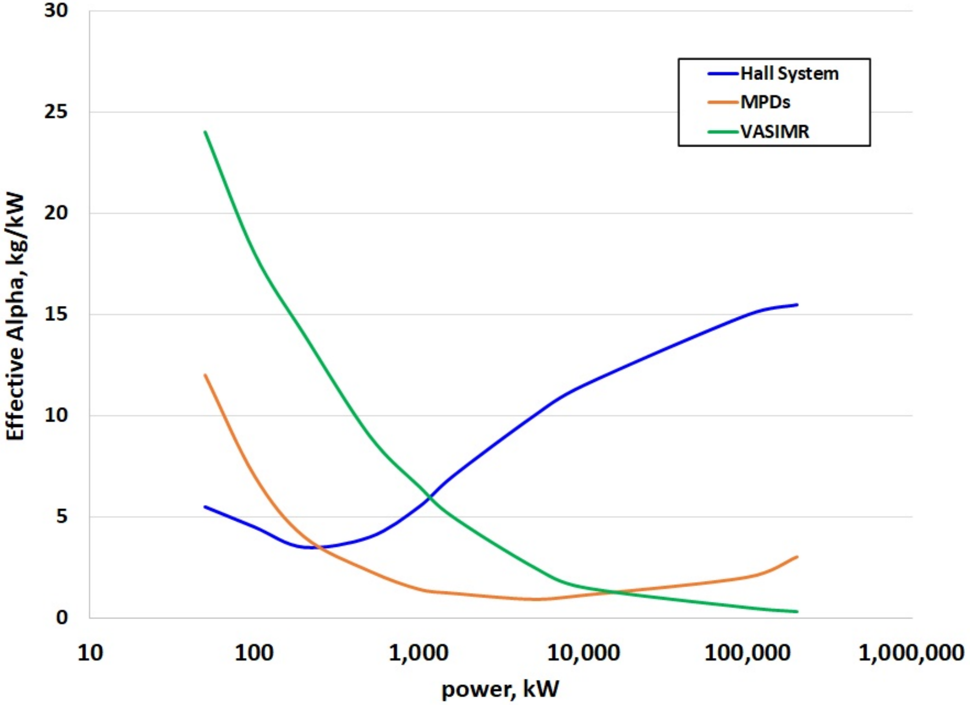

FORWARD
PORT
STARBOARD
AFT

Starboard view


ZENITH
AFT
FORWARD
NADIR


40–50 m

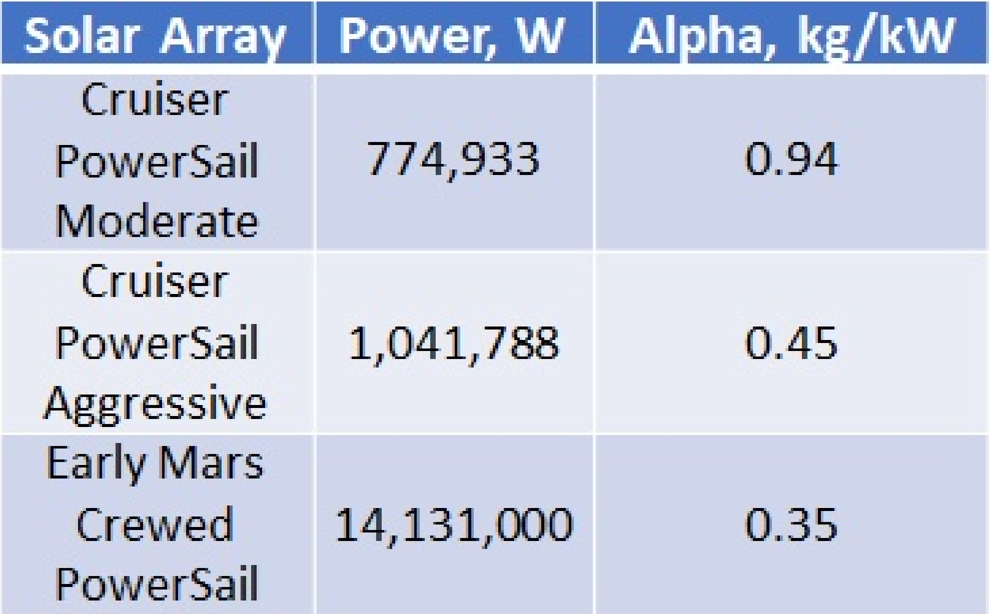



30
25
20
15
10
5
0
Effective Alpha, kg/kW
10
100
1,000
10,000
100,000
1,000,000
power, kW
Hall System
MPDs
VASIMR

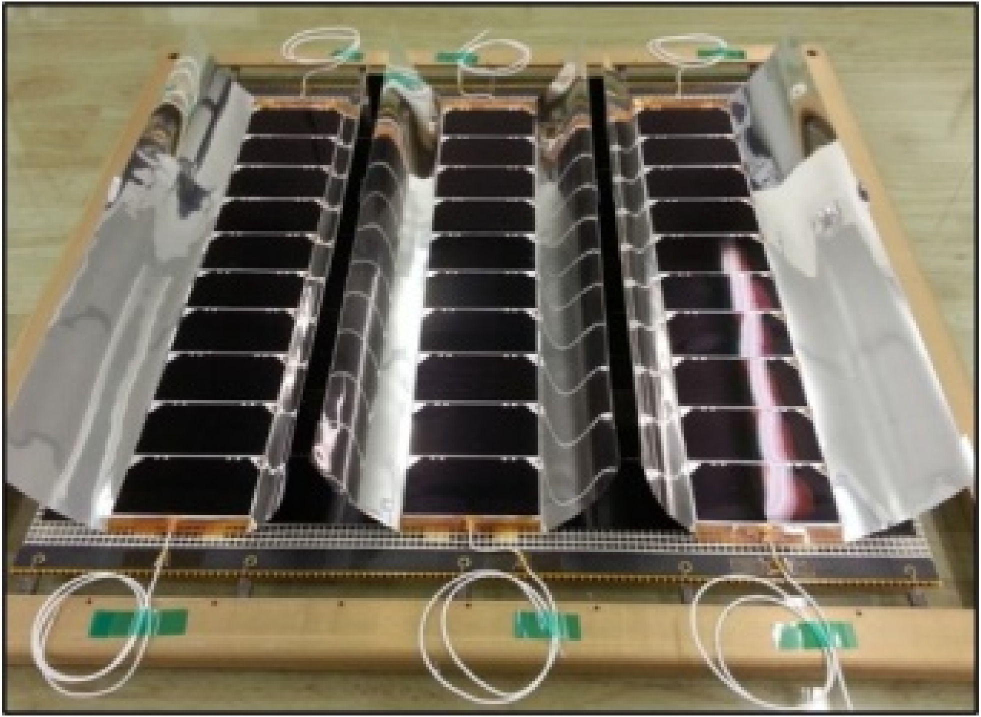
Subsystem	SOA	Far-Term Evolutionary	Transformative
CTE-1: Power Generation	16.5	1	0.05
CTE-2: Power Conversion	10	0.9	0.35
CTE-3: PMAD	6	2	0.07
CTE-4: Propulsion	5.5	2	0.5
CTE-5: Heat Rejection (w/o deployment mechanisms)	22 (13)	1	0
Total System, kg/kWe	51	7	0.97

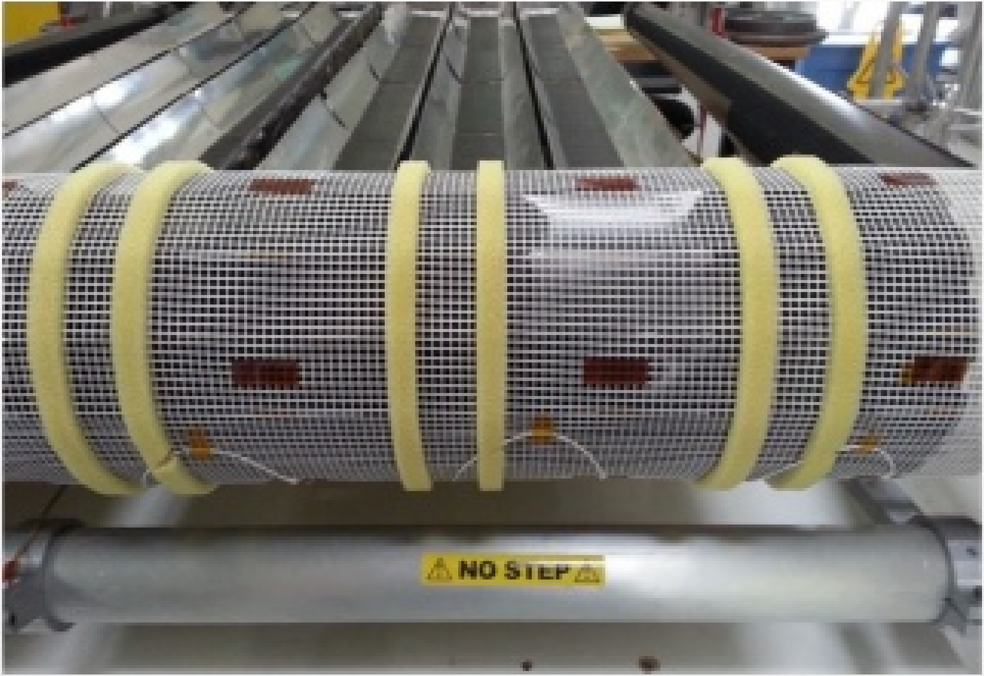
Solar Array	Power, W	Alpha, kg/kW
Rigid Panel Small (Hypothetical)	6,000	22.73
Rigid Panel Mid	25,000	12.50
Flexible fold-out	120,000	6.67
Flexible Roll Out Small (Hypothetical)	6,000	4.85
Flexible Roll-out Mid	25,000	6.67
ISS ROSA	34,000	13
Ultraflex Array (Hypothetical)	6,000	5.71
Lucy (Ultra Flex)	21,000	11.43
Insight (Ultra Flex)	1,840	10.65
Psyche	17,000	11.53

Solar Array	Power, W	Alpha, kg/kW
MegaFlex SEP Tug	300,000	5.20 - 6.45
MegaFlex Aggressive	10,000	3.80
ROSA/FACT	25,000	3.50 - 4.40
ROSA Evolved	242,000	3.40
Compact Telescoping Array	100,000	5.40
O’Neil Fresnel Array (small)	21,1000	1.52 - 1.90
O’Neil Fresnel Array (large)	321,400	4.1 - 5.00
Scout PowerSail Conservative	29,559	1.61
Scout PowerSail Moderate	26,645	0.89
JAXA OKEANOS Power Sail	108,254	0.84 - 1.30

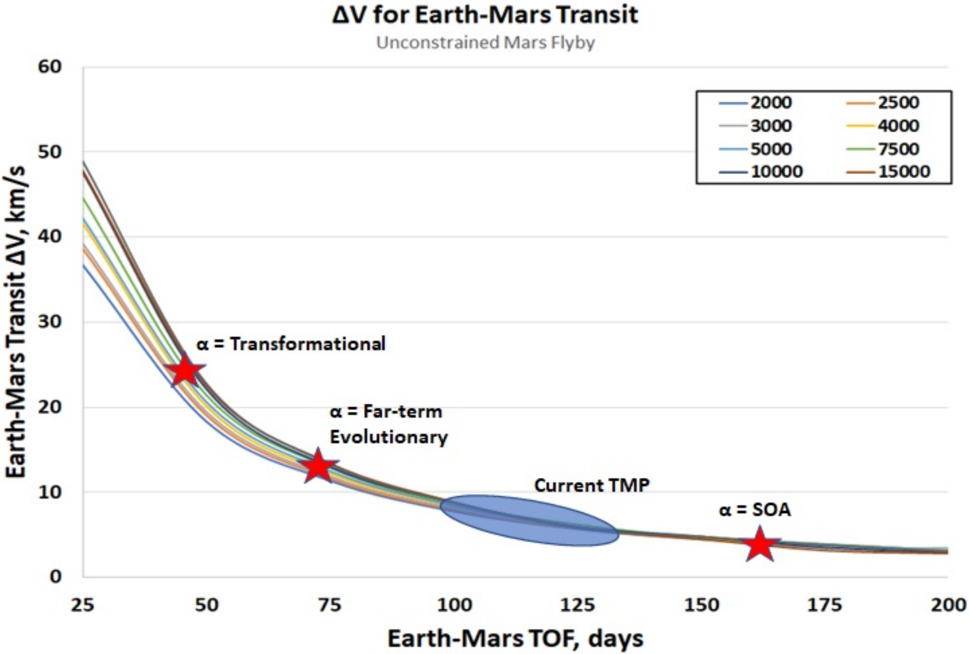


Solar Array	Power, W	Alpha, kg/kW
Cruiser PowerSail Moderate	774,933	0.94
Cruiser PowerSail Aggressive	1,041,788	0.45
Early Mars Crewed PowerSail	14,131,000	0.35



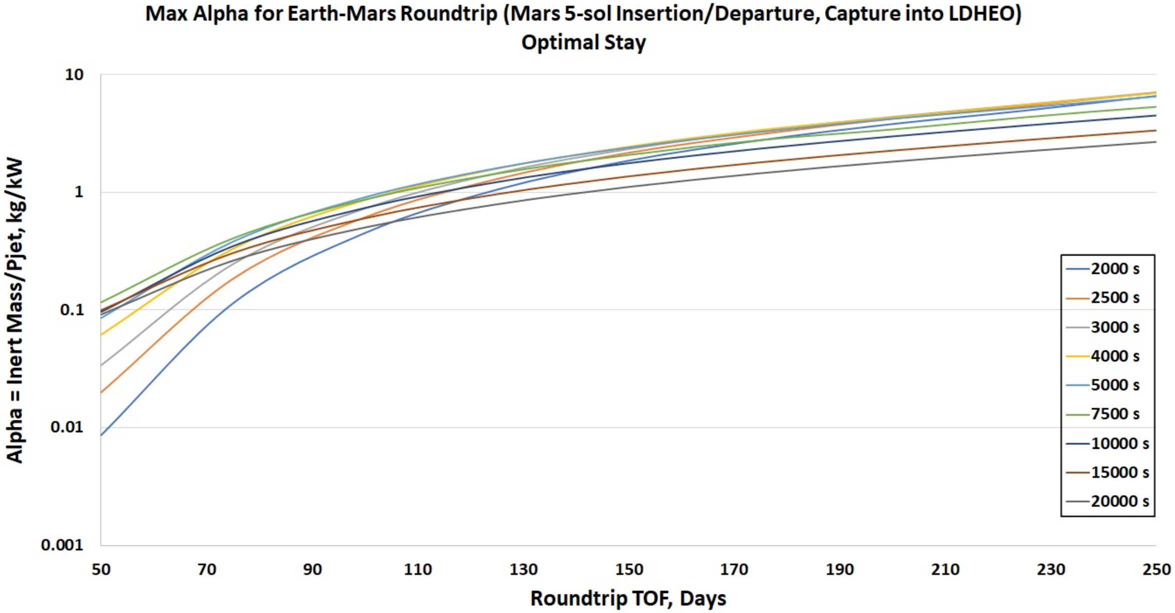

NO STEP

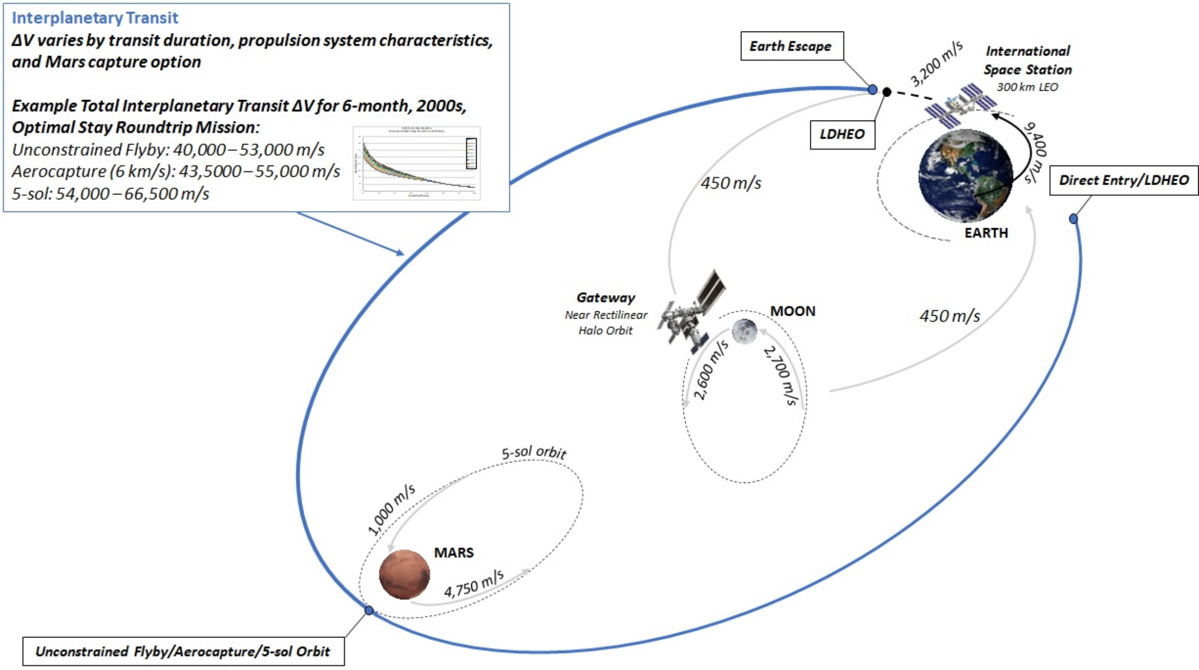
Subsystem	SOA	Far-Term Evolutionary	Transformative
CTE-1: Power Generation	6.67	0.84	0.35
CTE-2: Power Conversion	-	-	-
CTE-3: PMAD	2	2	0.07
CTE-4: Propulsion	5.5	2	0.5
CTE-5: Heat Rejection	4.4	0.2	0
Total System, kg/kWe	19	5	0.92



ΔV for Earth-Mars Transit

Unconstrained Mars Flyby


Max Alpha for Earth-Mars Roundtrip (Mars 5-sol Insertion/Departure, Capture into LDHEO)
Optimal Stay
Alpha = Inert Mass/Pjet, kg/kW
10
1
0.1
0.01
0.001
Roundtrip TOF, Days
50
70
90
110
130
150
170
190
210
230
250
2000 s
2500 s
3000 s
4000 s
5000 s
7500 s
10000 s
15000 s
20000 s



Interplanetary Transit

ΔV varies by transit duration, propulsion system characteristics, and Mars capture option

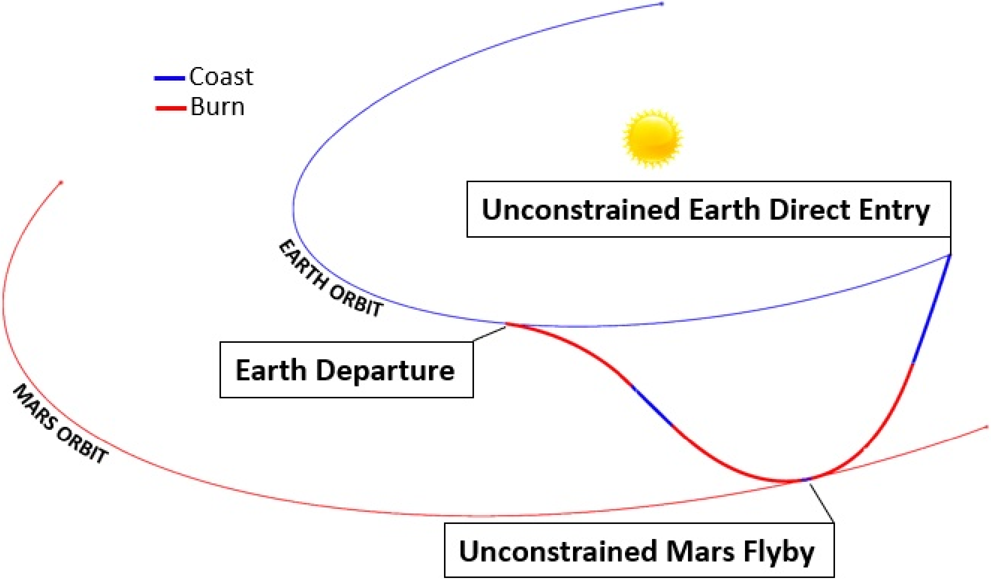
Example Total Interplanetary Transit ΔV for 6-month, 2000s, Optimal Stay Roundtrip Mission:

Unconstrained Flyby: 40,000–53,000 m/s

Aerocapture (6 km/s): 43,5000–55,000 m/s

5-sol: 54,000–66,500 m/s

Earth Escape
3,200 m/s
International Space Station
300 km LEO
LDHEO
9,400 m/s
Direct Entry/LDHEO
EARTH
450 m/s
Gateway
Near Rectilinear Halo Orbit
MOON
2,600 m/s
2,700 m/s
450 m/s
5-sol orbit
1,000 m/s
MARS
4,750 m/s
Unconstrained Flyby/Aerocapture/5-sol Orbit


Coast
Burn
Unconstrained Earth Direct Entry
EARTH ORBIT
Earth Departure
MARS ORBIT
Unconstrained Mars Flyby